Progress report
Fast and lightweight tracking systems
Forward Triple-GEM

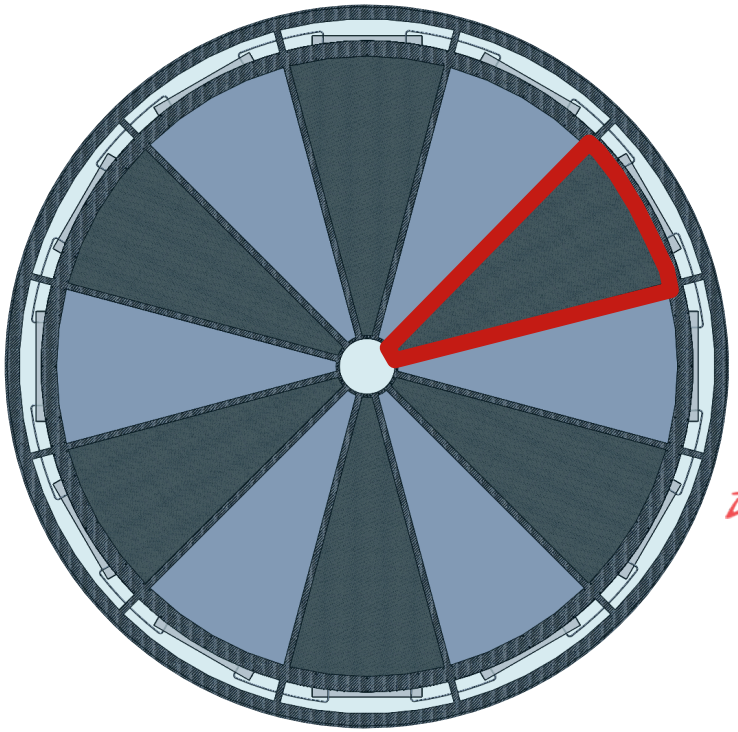
Maxence Vandenbroucke
Bernd Surrow

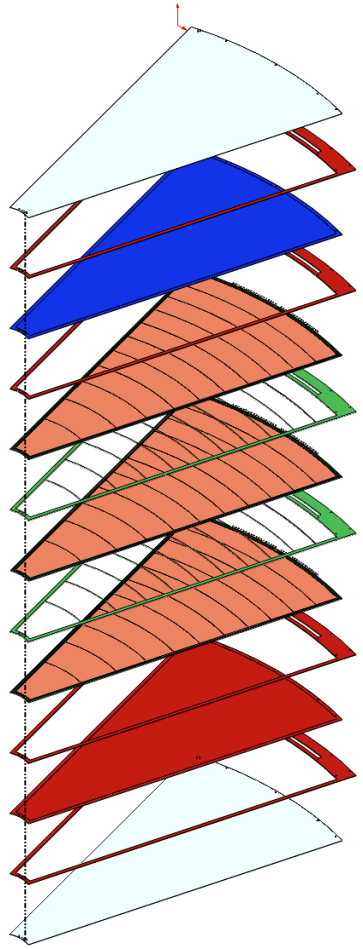
TEMPLE UNIVERSITY

PI's:
Frank Sabatie & Bernd Surrow

Outline

- Project overview
- TU - Manpower / Infrastructure / Computing resources
- Simulations
- Commercial GEM foil fabrication
- TU - Laboratory setup / capabilities
- Large triple-GEM design work
- Summary





Project Overview

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Design and assembly of fast and lightweight barrel and forward tracking prototype systems for an EIC

S. Aune, E. Delagnes , M. Garçon, I. Mandjavidze, S. Procureur, F. Sabatié[1]
CEA Saclay - Irfu

B. Surrow[2]
MIT / Temple University

D. Hasell, R. Milner, B. Redwine, G. van Nieuwenhuizen
MIT, Laboratory for Nuclear Science

B. Buck, J. Bessuille
MIT, Bates Laboratory

Project Overview

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  - Extensive previous experience and resources

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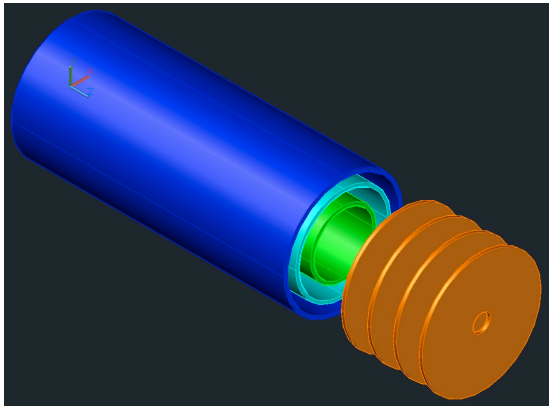
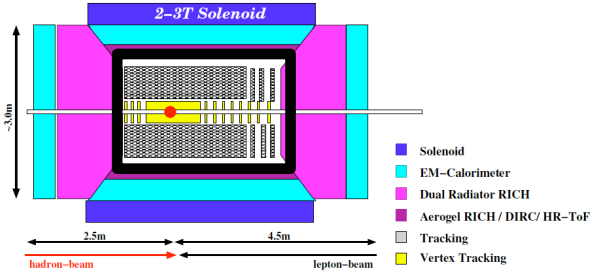
  - MicroMegas / GEM technology: Well-suited for EIC application providing a cost-effective solution





EIC Whitepaper 2012

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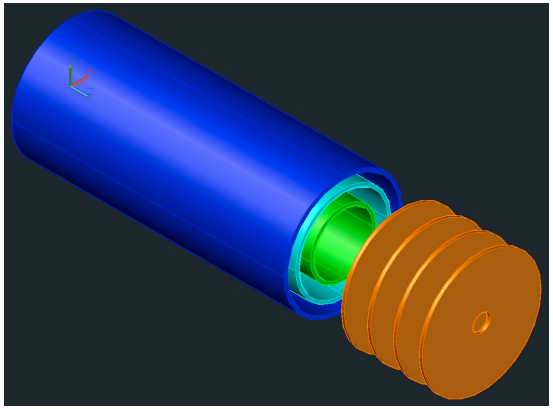

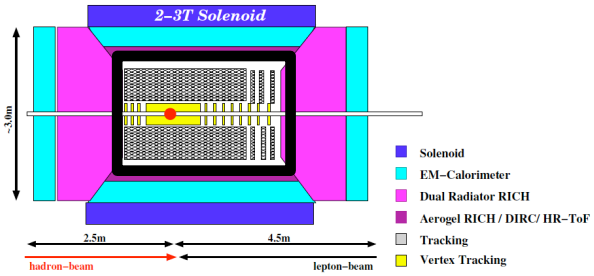

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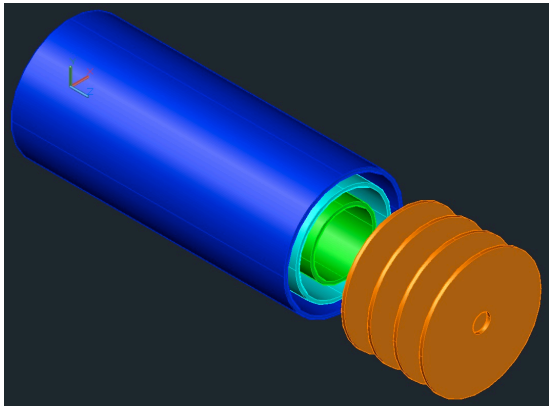

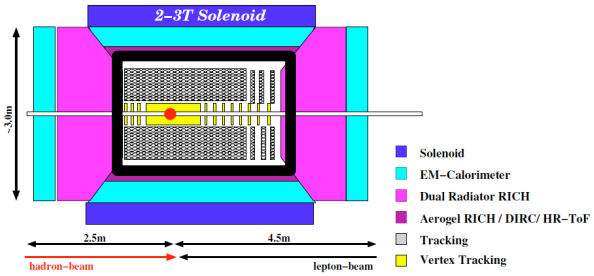

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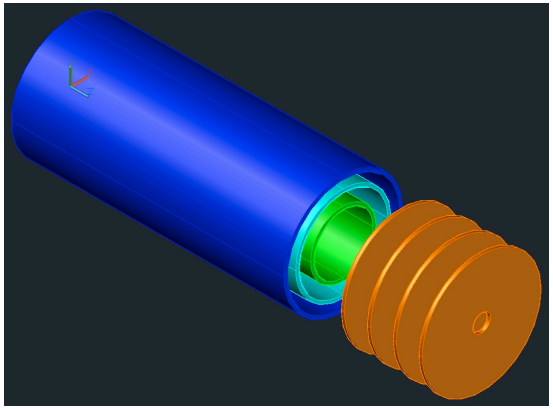
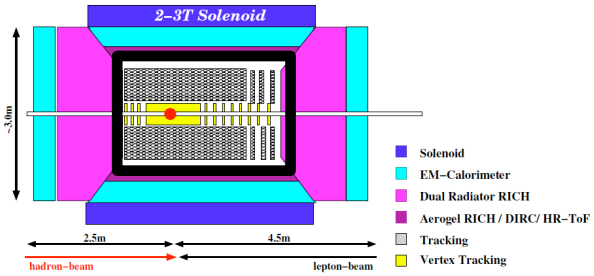
- Specify layout, in particular readout layer through detailed simulations
- Build and test full size prototype collaborating directly on test equipment, resources incl. man-power and FEE development



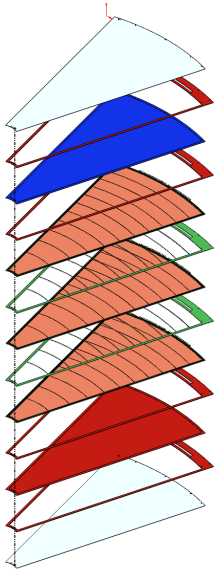


EIC Whitepaper 2012

Project Overview

- Status
  - Manpower:
    - Interview of Dr. Maxence Vandenbroucke (PhD TU Munich / Paris 6) in March 2012 at Saclay
    - Starting date at TU October 2012 following grant setup at TU in August 2012
    - Attracted several undergraduate (7) and graduate students (4) at TU

- Focus so far: Forward Triple-GEM part (Maxence at TU, October 2012 - April 2012)
- Next: MicroMegas (Maxence at Saclay, April 2012 - October 2012)
- EIC R&D grant is fully managed by TU CST
- Setup of lab at TU in progress / Purchase various items from R&D grant
- Simulations started
- Design of full prototype started
- Process of commercial fabrication of large GEM foils started



SOLIDWORKS

Temple University - Manpower

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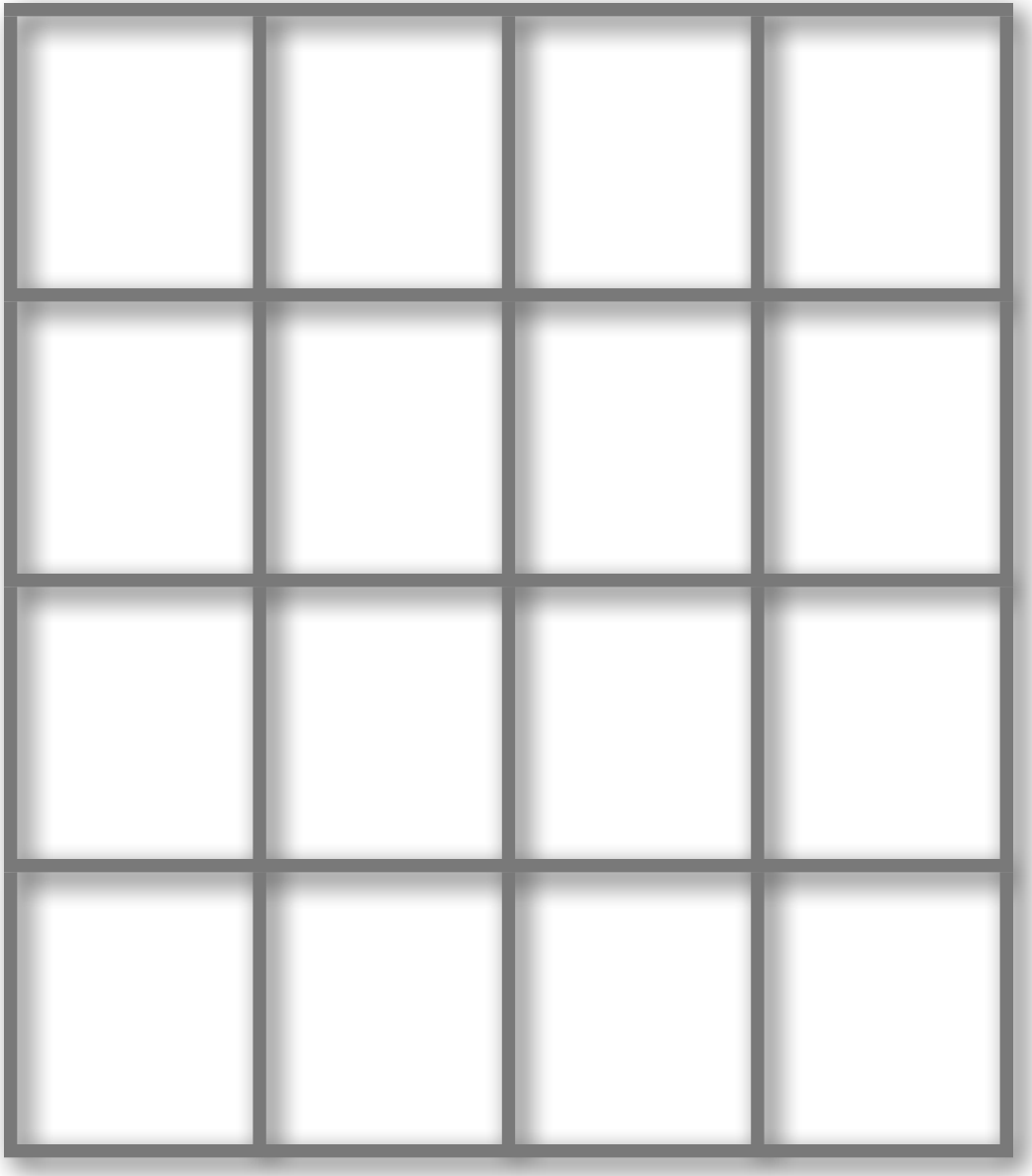

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- Technical staff
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  - Electronics technician (right): Richard Harris

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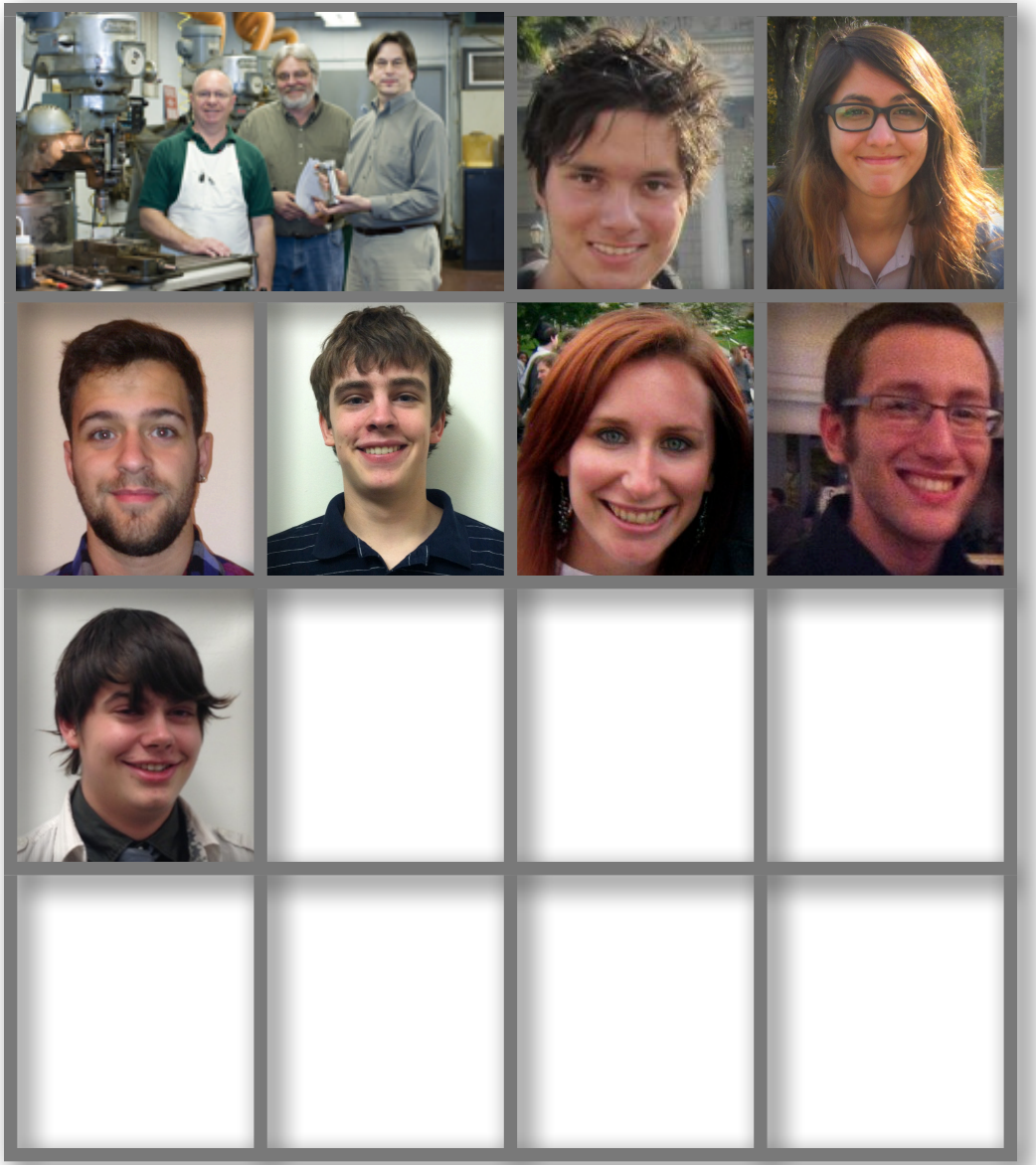

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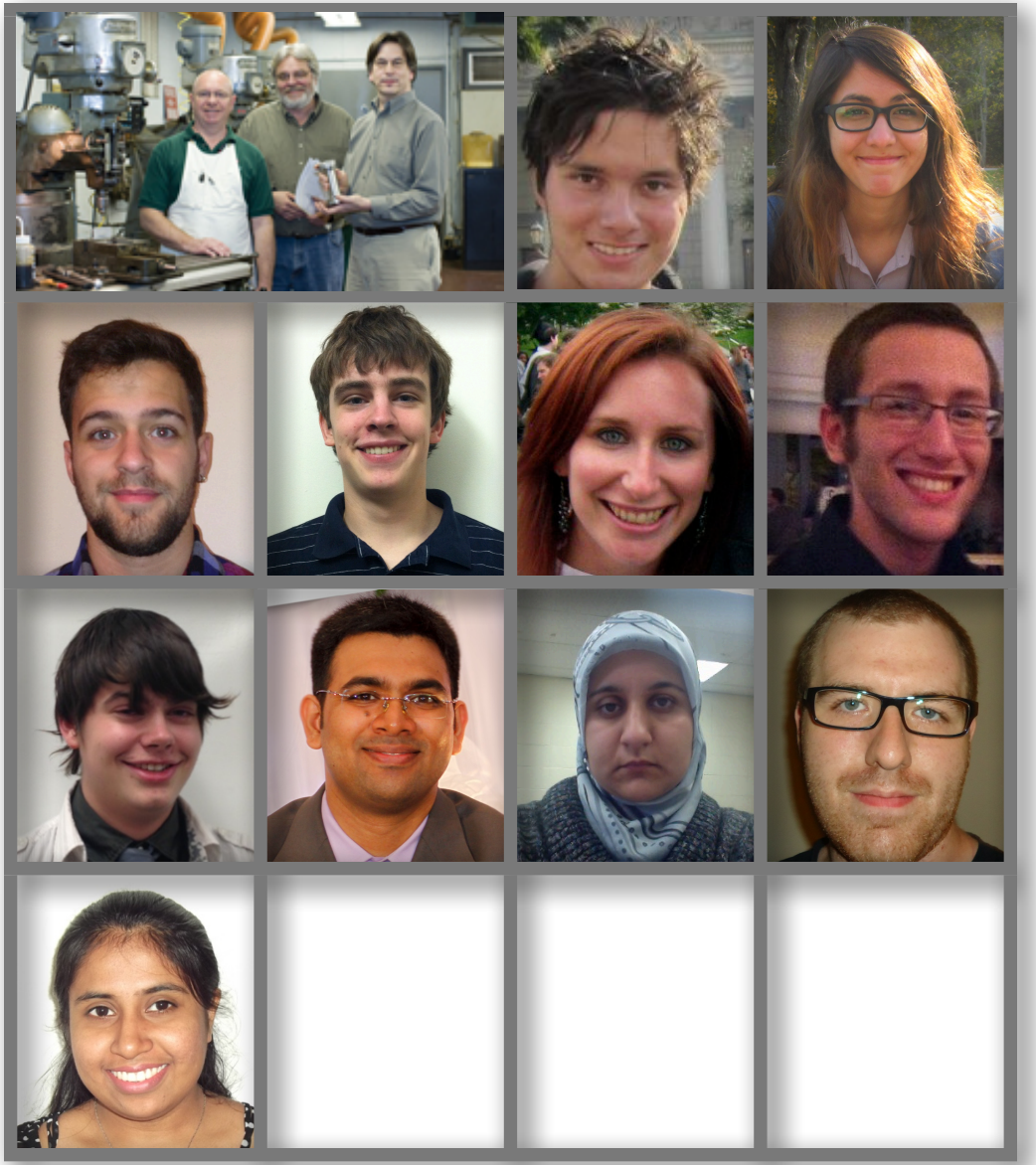

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Temple University - Infrastructure

- Current physics department ('Barton Hall') until 2014
  - Two labs are in the process of being setup :
    - Detector lab
    - Dedicated, existing clean room lab

  - Lab maintenance and support provided by TU CST
  - Various lab items have been purchased out of EIC R&D grant and other items are either already at TU or will be moved from MIT to TU next week following the completion of the STAR Forward GEM Tracker

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- New Physics Department starting 2014

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  - 4th floor:
    - Dedicated detector lab: ~800 sq. ft.
    - Maintenance provided by TU
  - 5th floor:
    - Class 1,000 clean room: ~1,800 sq. ft. / GEM + Silicon lab
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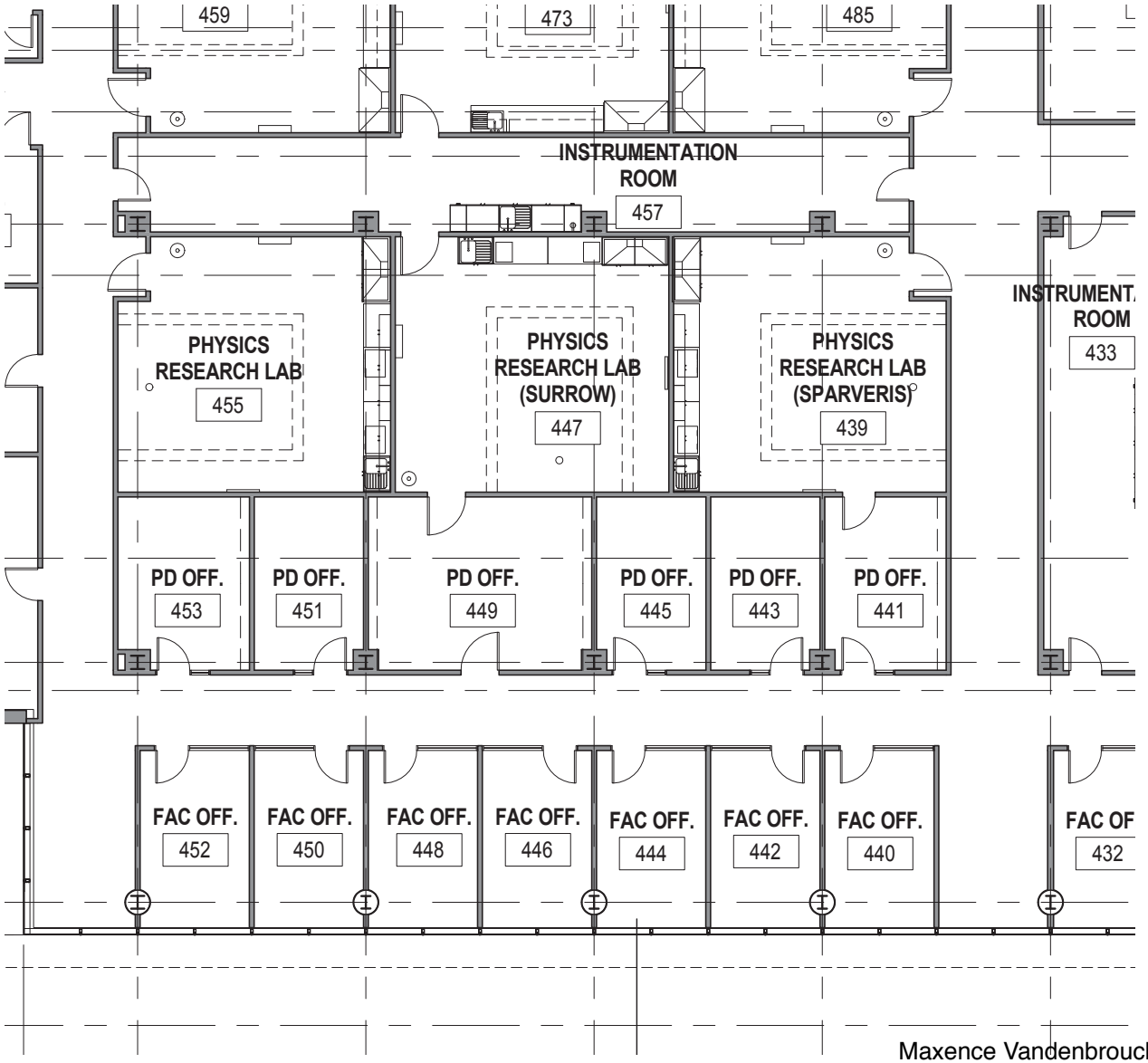
  - Both labs are exclusively provided for the HEP / Detector research group (B. Surrow)



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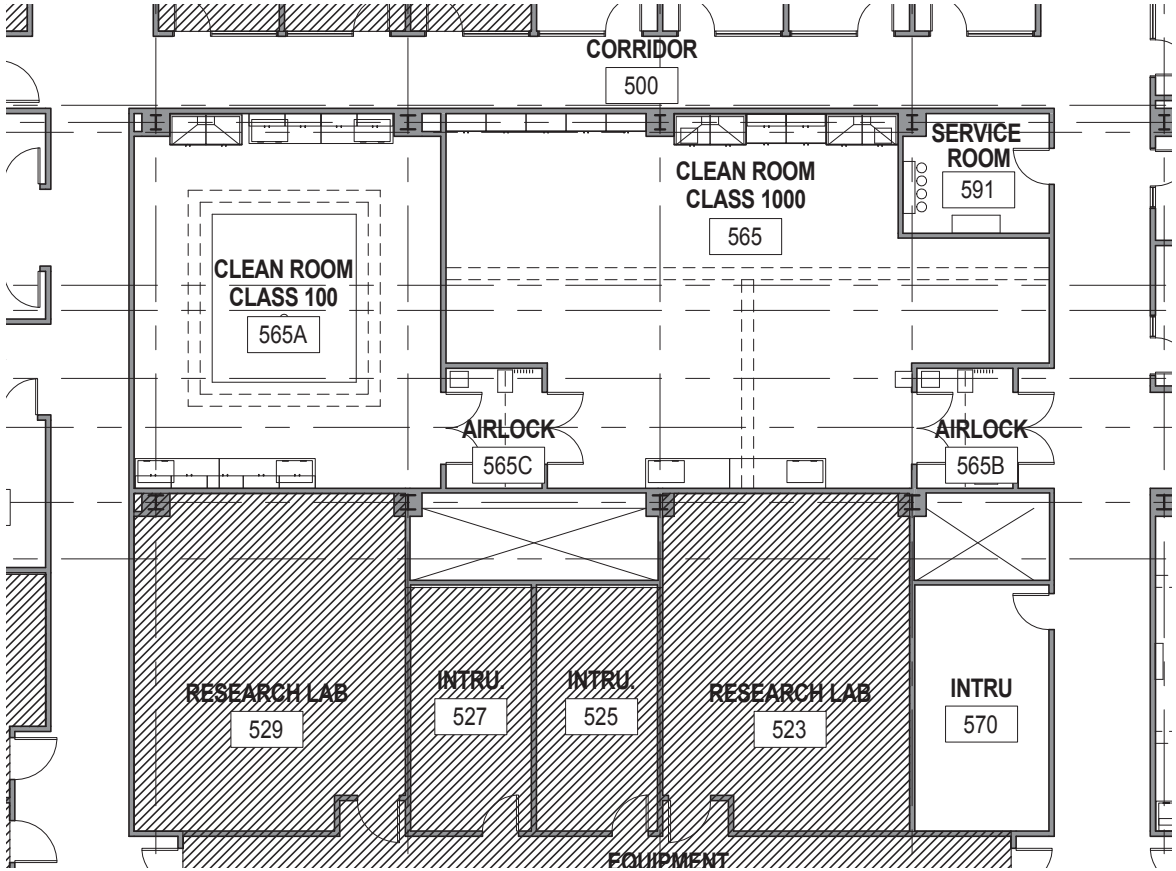
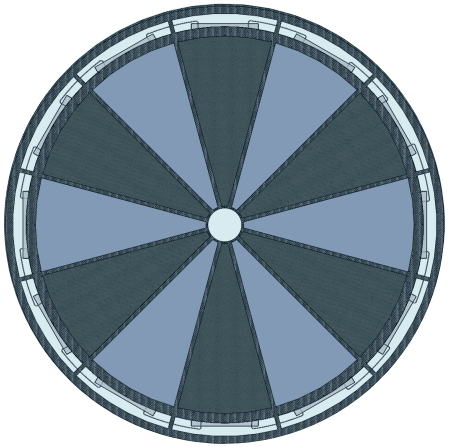


Temple University - Computing resources

- Computing cluster
  - TU CST high-performance computing cluster for CST faculty research (Owl's Nest)
    - ~1500 CPU cores
    - ~120TB storage
  - Maintenance provided by TU CST
  - Support for MC production using full installation of experiment specific framework and /or cloud computing application
  - Standalone MAC OSX computing cluster
  - Design tools: SolidWorks and AutoDesk on standalone MAC OSX server using VMWare

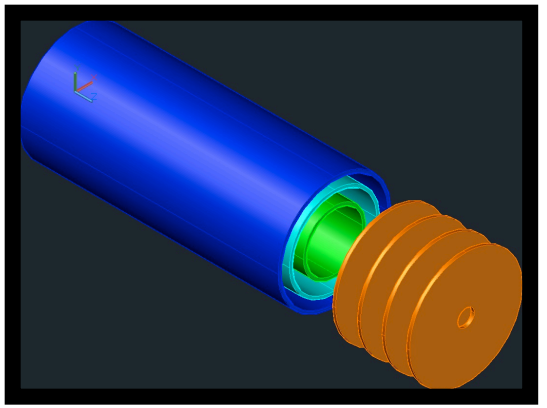
Owl's Nest at TU CST

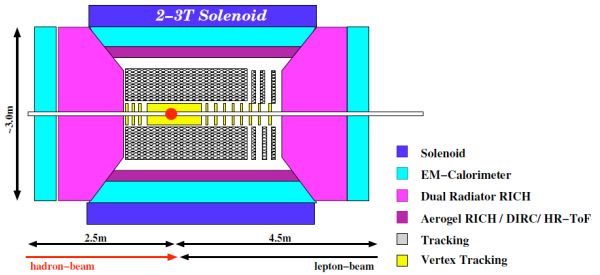


Simulations

Considerations on Tracking System

- Tracking over wide acceptance range: Forward with ~1° and Rear with ~179°, excluding very forward / rear detector regions
- Contribute to reconstruction of event kinematics besides calorimetry in particular at very small energies
- High-rate environment (~10MHz ep collisions)
- Fast time response
- Precision hit resolution, e.g. low Q^2 region
- Minimal dead material (~1% X_0)
- Cost effective solution for large tracking detector areas
- Simulations: (A) Analytical acceptance / resolution studies and (B) Full GEANT 4 simulations



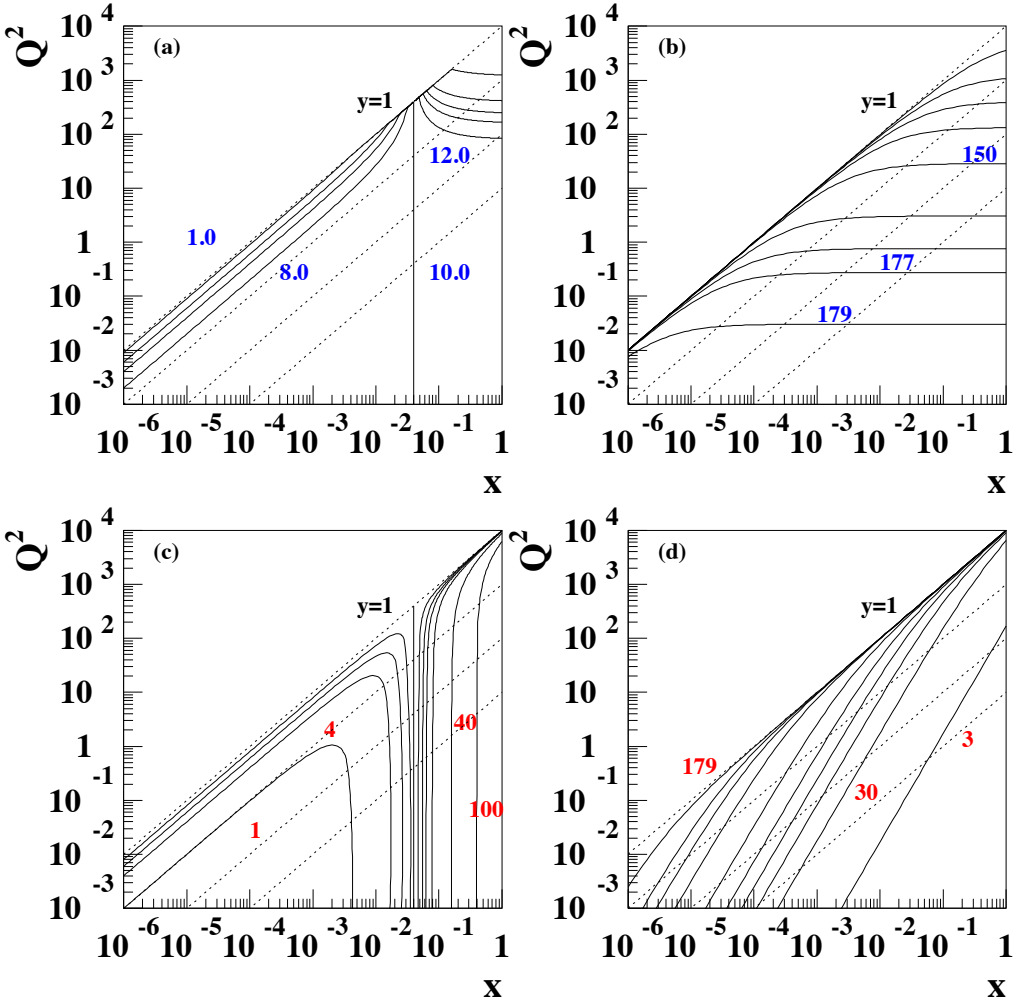


EIC Whitepaper 2012

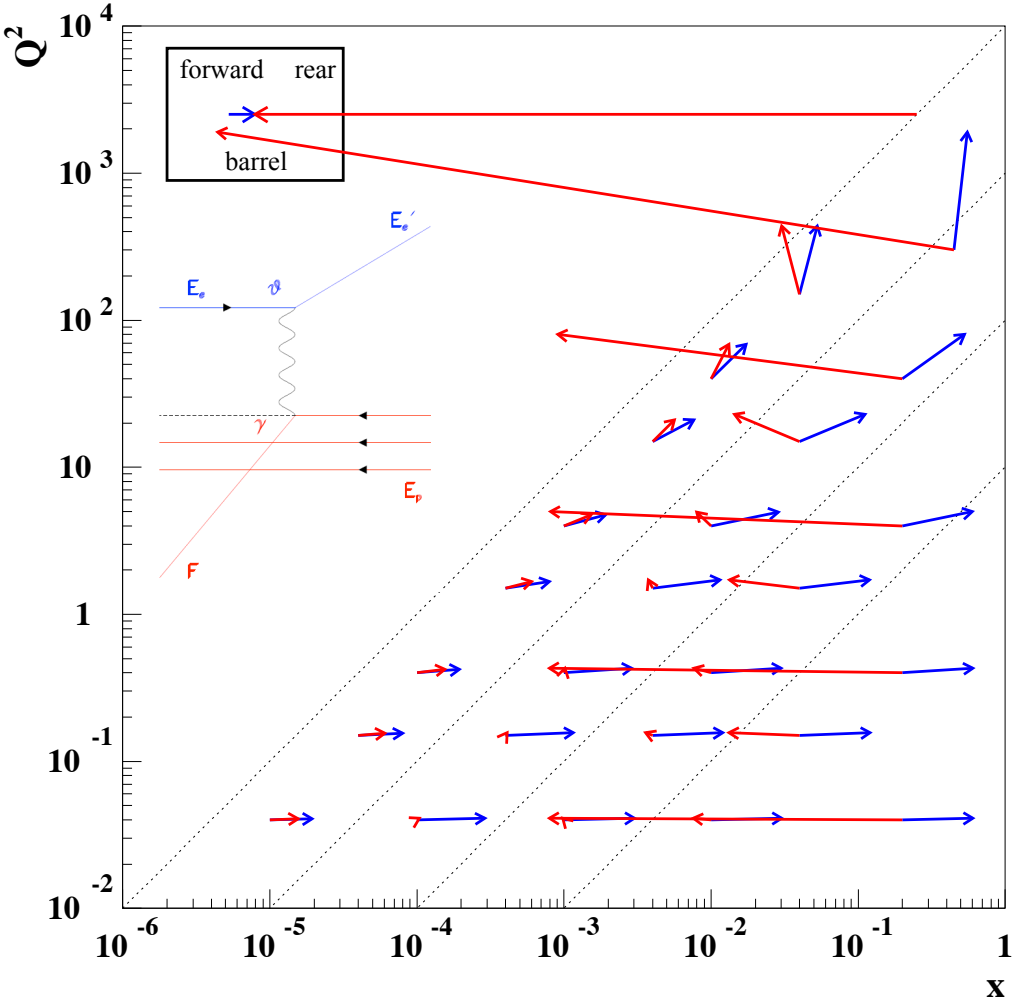
Simulations

- Analytical acceptance / resolution studies (1): 10GeV (e) X 250GeV (p)

EIC kinematics (E_e=10 GeV, E_p=250 GeV)



EIC event topology (E_e=10 GeV, E_p=250 GeV)



$$E_e/E_p = 0.04$$

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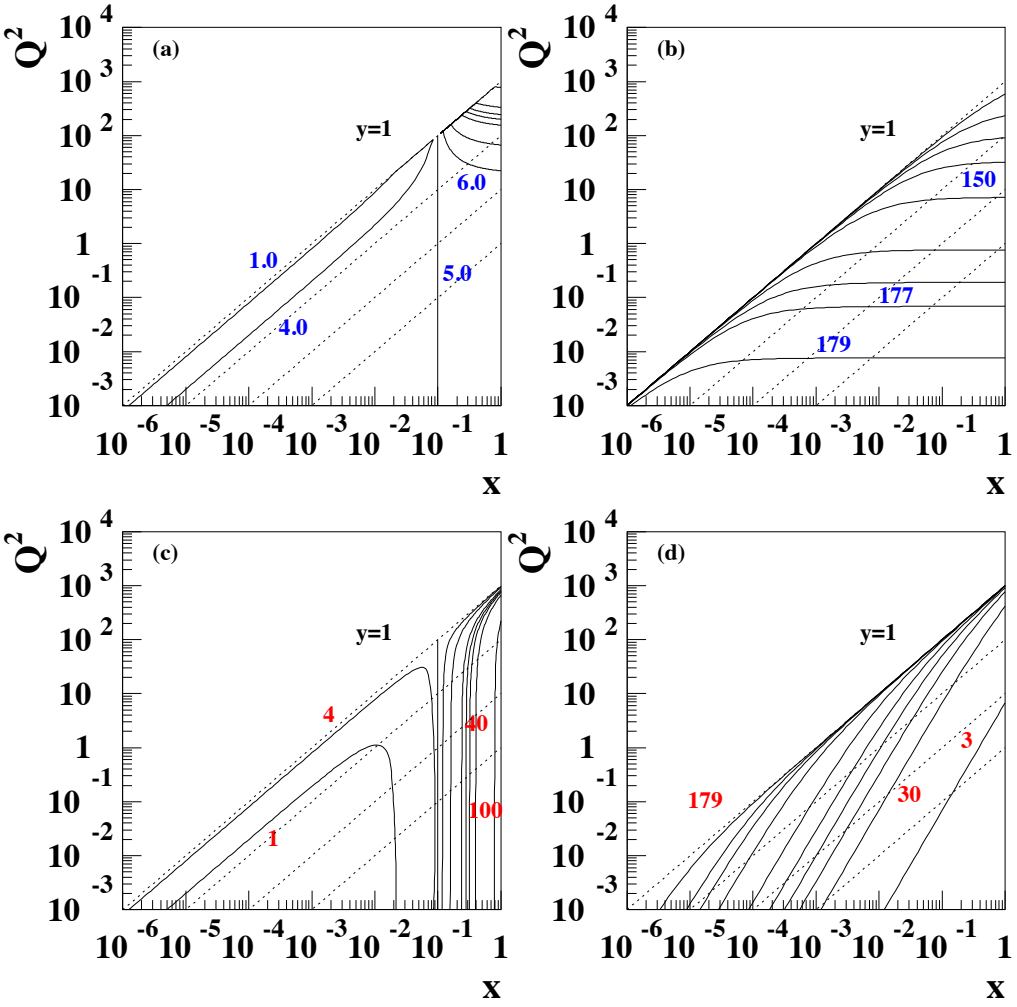
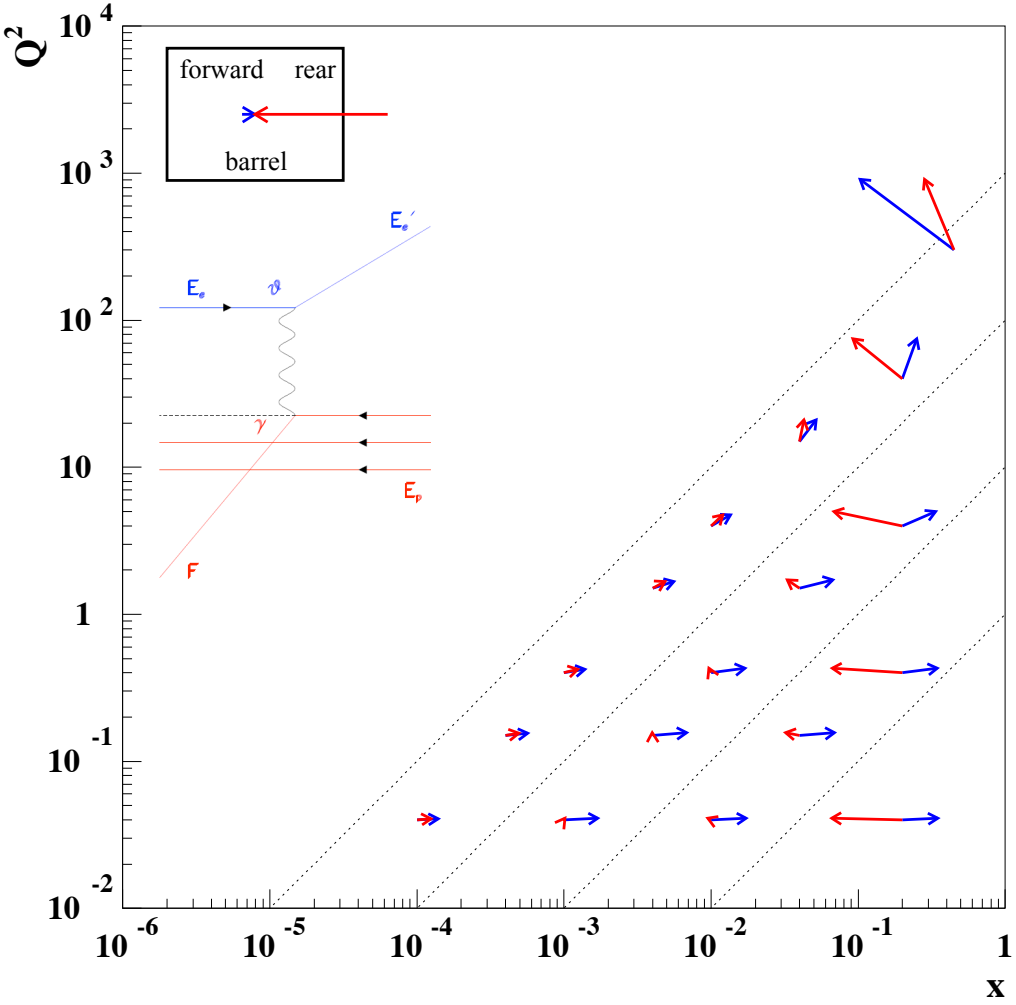
Simulations

- Analytical acceptance / resolution studies (2): 5GeV (e) X 50GeV

EIC kinematics (E_e=5 GeV, E_p=50 GeV)



EIC event topology (E_e=5 GeV, E_p=50 GeV)



$$E_e/E_p = 0.1$$

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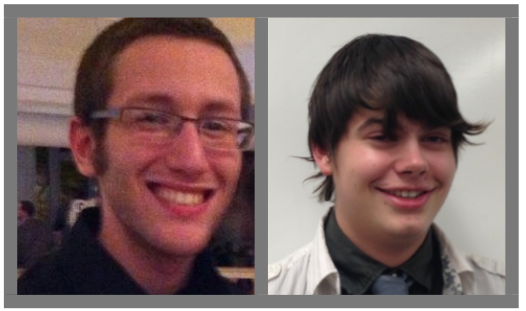
Simulation - GEANT4

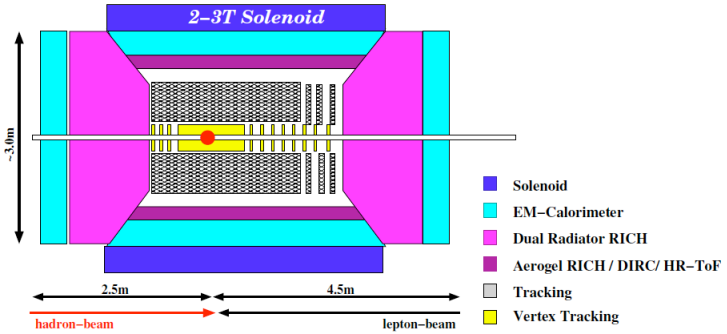
- EIC detector simulation - GEANT4



- Two double-major students in physics and computer-science (Brandon and Jake) familiar with C++/Perl and GEANT4

- Setup of standalone GEANT4 simulation framework profiting from the experience gained by Dr. Doug Hasell at OLYMPUS / Code already installed and running!

- Begin with Whitepaper 2012 layout starting point of geometry and material definition focusing on tracking system

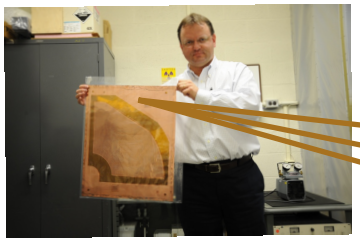


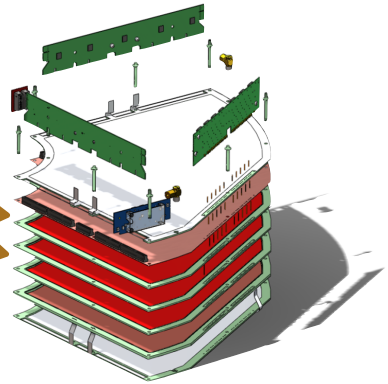
- First results expected in spring 2013 with emphasis on micro-pattern tracking system

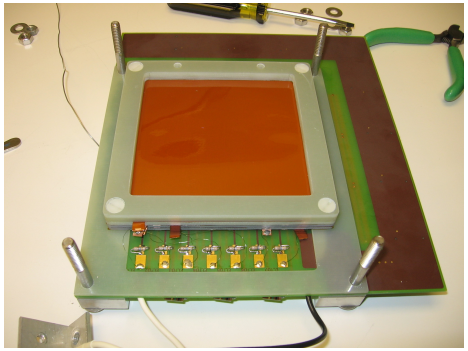
Commercial GEM foil fabrication

- Status of large GEM foil production
  - Step from 10cm X 10cm foils to larger foils driven initially by STAR Forward GEM Tracker project
  - Status: Successful production (double mask) of foils in terms of optical uniformity and leakage current performance

FGT GEM foil





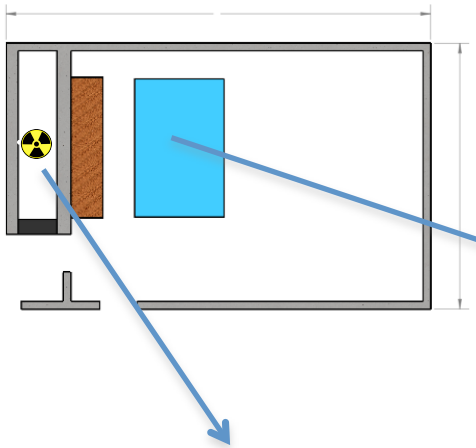


10cm X 10cm foils

  - Next major step:
    - Increase size to 100cm X 50cm
    - Establish single mask production process at Tech-Etch Inc. / Strong interest by CERN group (R. de Oliveira) : CMS Muon upgrade project
    - Recent meeting with CERN / Temple University and Tech-Etch resulted in agreement to work together on technology transfer
    - Independently, BNL, MIT, Temple University and Yale might submit a new SBIR proposal in collaboration with Tech-Etch Inc. / Discussion with DOE required (Employee limit of 500 vs. 515 employees now)

Laboratory setup / capabilities

- Detector lab (1)



Radioactive source storage room

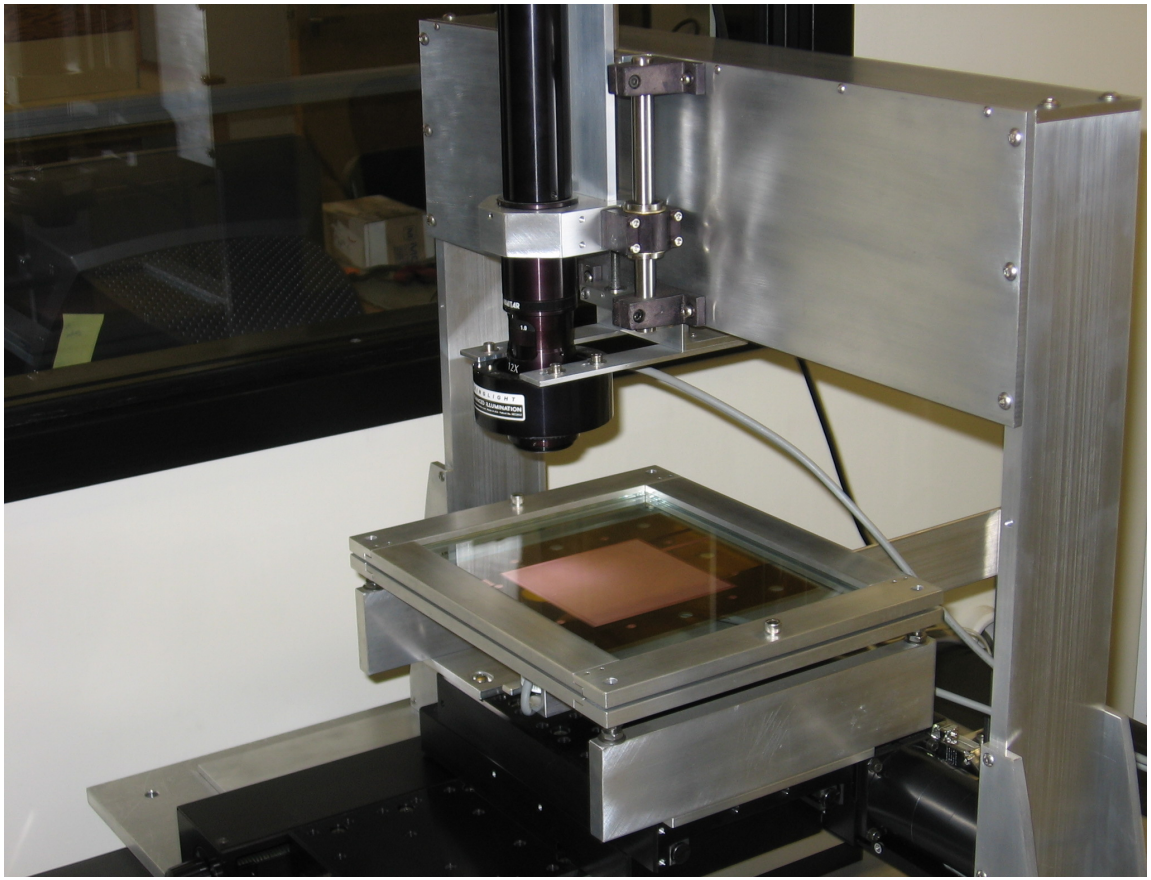
12x8 ft^2 modular clean area

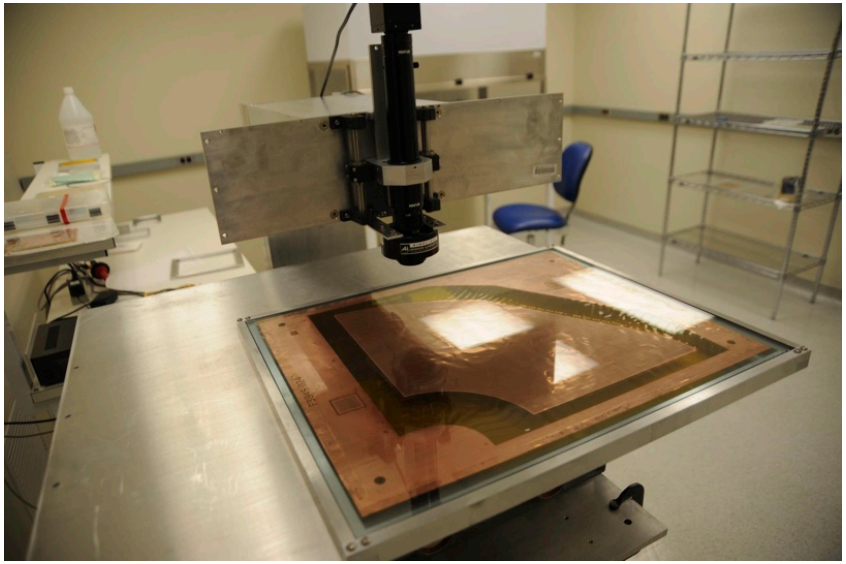
Moving / Installation ongoing

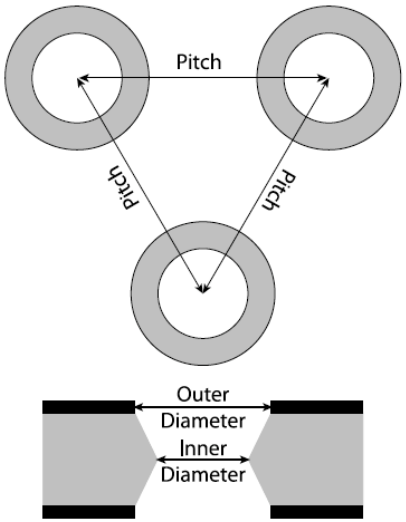
- Detector test and characterization (Detector lab B11, Barton Hall):
  - Geometry measurements with CCD camera setup
  - Detector gain measurement with radioactive source (^{55}Fe)
  - Detector characterization with cosmic rays
  - Readout electronics test
  - DAQ commissioning

Laboratory setup / capabilities

- Detector lab (2)







- Optical uniformity based on existing CCD camera setup

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Laboratory setup / capabilities

- Clean room (1)

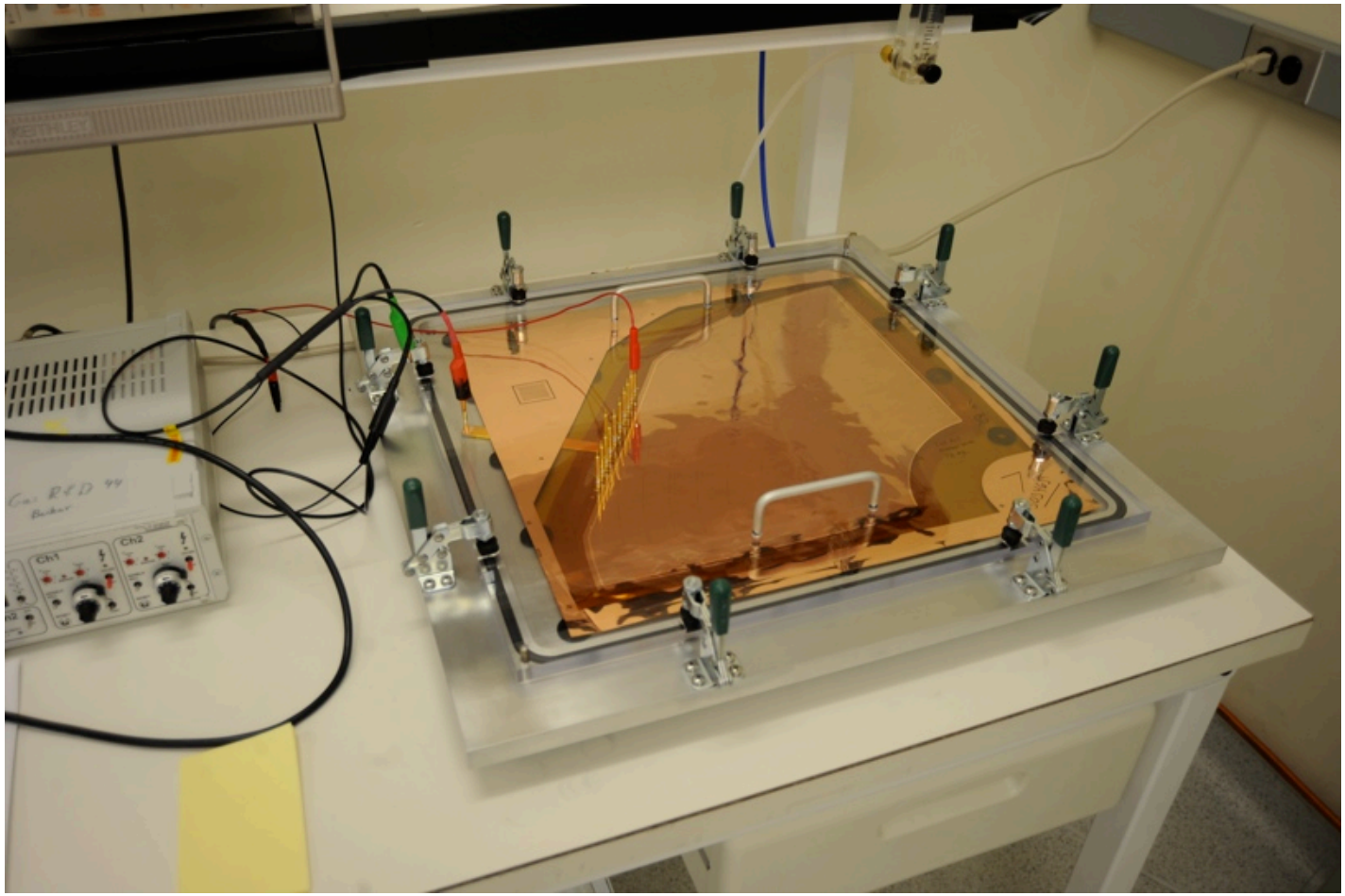
Existing cleanroom at Temple

Benches reserved for GEM R&D work

- Activities that require the manipulation of bare foils:
  - Visual inspection of GEMs
  - Preparation for CCD camera tests
  - Leakage current measurements
  - Assembly of detectors

Laboratory setup / capabilities

- Clean room (2)



- HV box for GEM foil leakage current tests

Laboratory equipment

Available / existing equipment

- **HV units:** Multi-channels HV power supplies with nano-amp precision
- **NIM / VME units:** Crate + standard modules
- **Data Acquisition System (DAQ):** Complete detector readout electronic system
- **Gas system:** Nitrogen for leakage current measurements, Ar/CO2 for gain calibration + control/monitoring system
- **CCD Scanner:** Automated system for optical scan of GEM foils
- **XY table:** Gain homogeneity automated scans with 55Fe source
- **Nitrogen Boxes:** Gas-tight volume for leakage current measurements
- **Stretching / Assembly fixtures:** Apparatus for detector assembly
- **Cosmic-rays trigger:** Plastic scintillators + coincidence units
- **Two 10x10 cm2 prototypes:** Small triple GEMs detectors for GEM foil characterization and cosmic-ray tracking
- **FGT prototypes:** 90° sectors for test and cosmic-ray tracking
- **Software licenses :** SolidWorks, AUTOCAD, and Labview

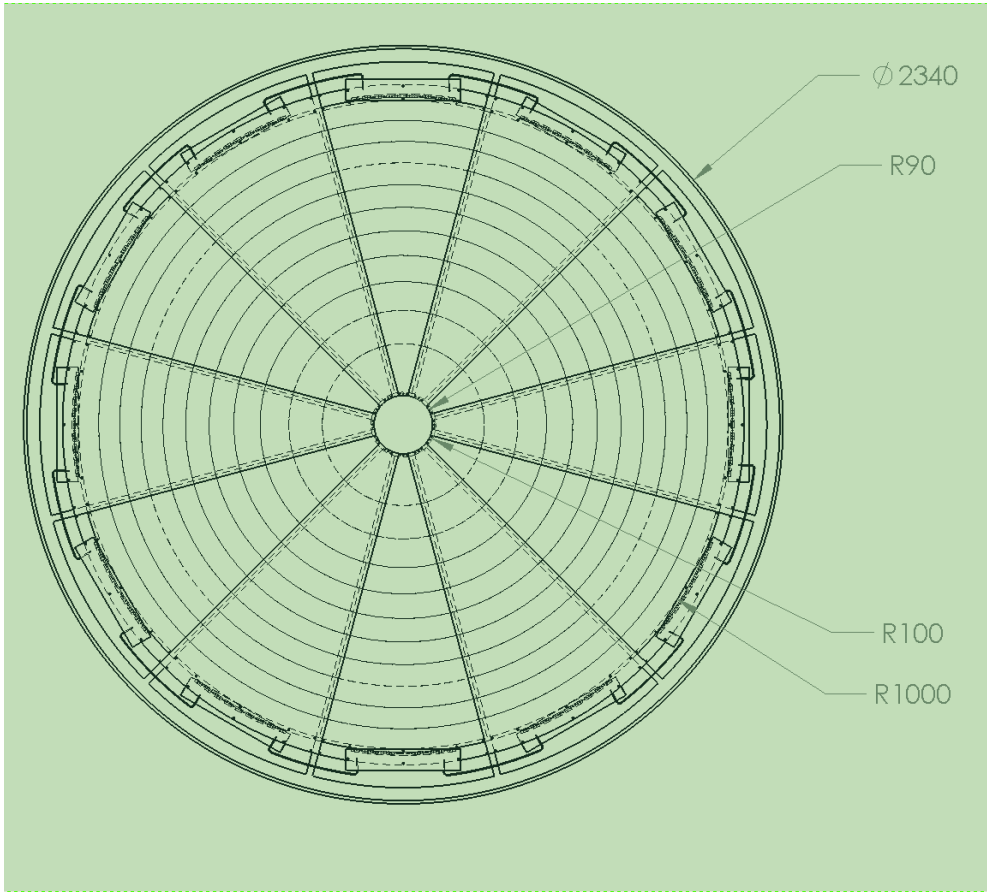
Laboratory equipment

- Lab equipment purchased through EIC R&D grant

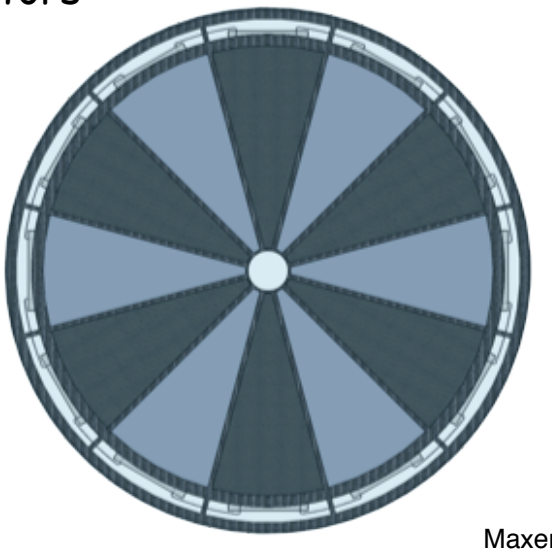
  - **Scope:** Tektronix TDS2024C with CPU interface
  - **Multi-Channel Analyzer:** AmpTek MCA8000D for gain measurement
  - **Pre-amplifier:** ORTEC 142A low-noise charge amplifier
  - **Amplifier:** ORTEC 570 low-noise amplifier optimized for spectroscopy
  - **Pulser:** ORTEC 480 voltage pulse generator for measurement chain calibration
  - **Soldering iron:** Weller WD1002 + WTA50 tweezers for SMD components
  - **Modular cleanroom:** Terranova Universal, 12'L x 8'W x 8'H, class 10,000
  - **^{55}Fe radioactive source:** 5.9KeV X-ray emitter for gain measurements

Large triple-GEM design work

Design overview



- Layout implemented in Solidworks
- Active area 10cm < R < 100cm
- 30 degree detectors (Base material constrain)
- 12 triple-GEM detectors with 2D readout
- No dead zone
- Light weight support structure and detectors



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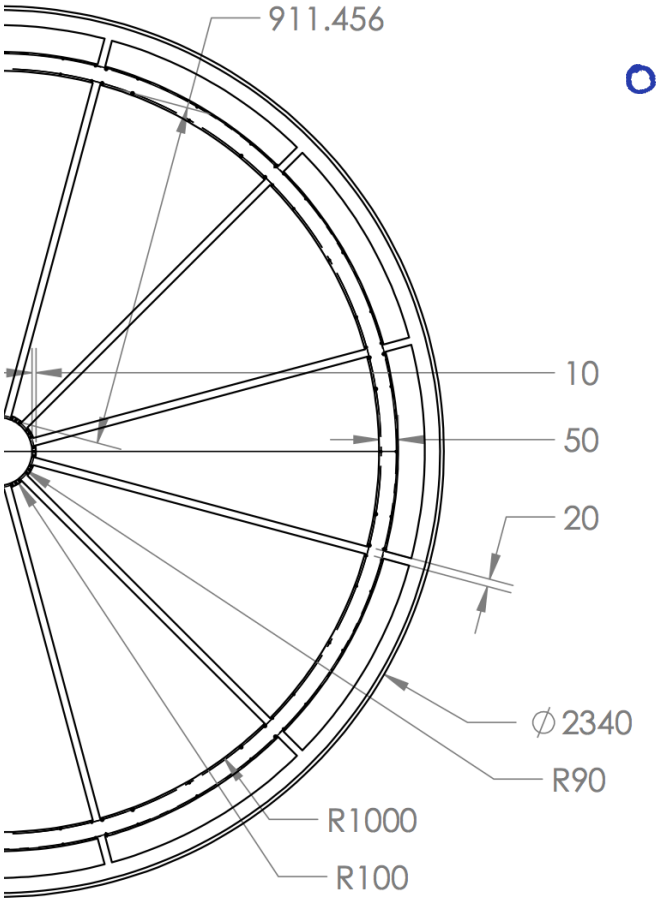
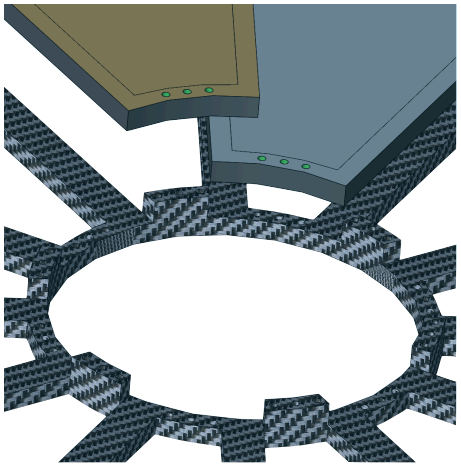
Large triple-GEM design work

- Support wheel



Wheel dimensions (cm)

- Light weight wheel support
- Detectors stacked face-to-face to optimize the thickness of 1 station



Detector installation

Wheel support frame

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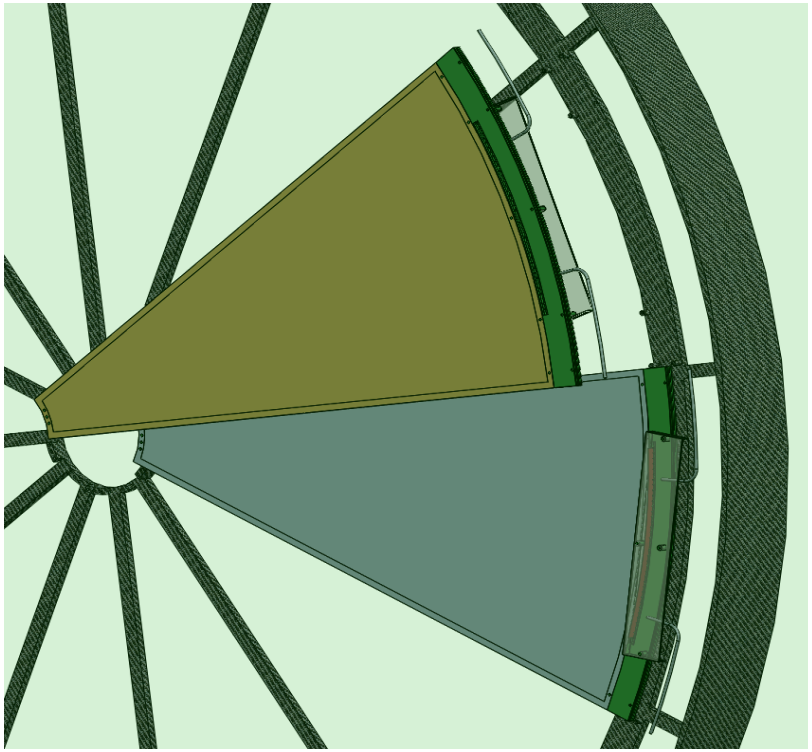
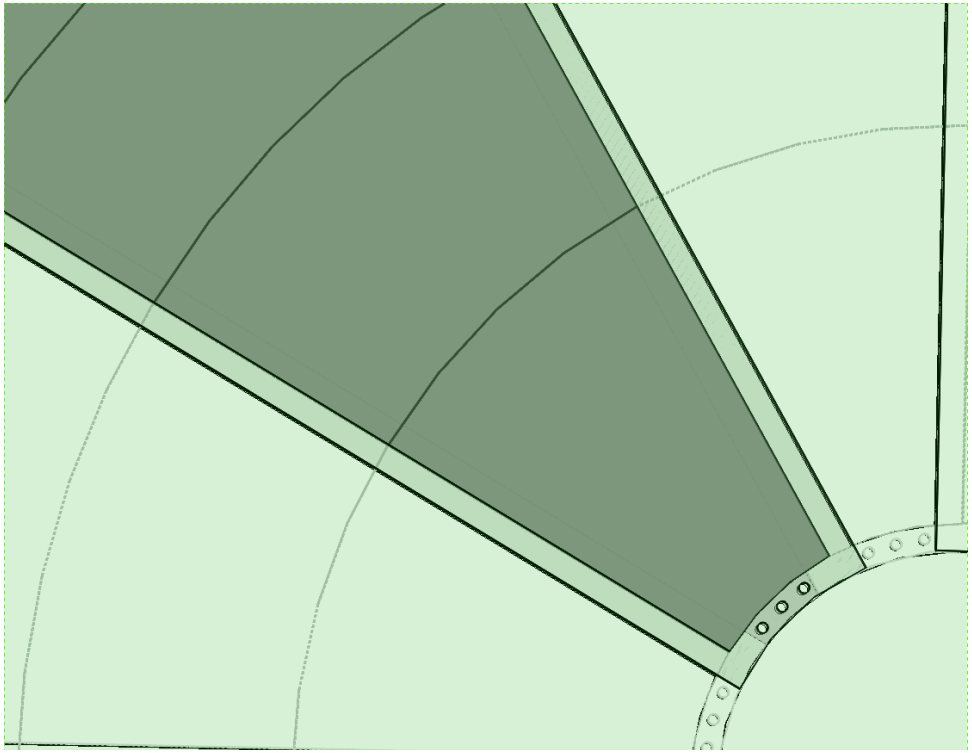
Large triple-GEM design work

- Assembly of detectors on support structure



Detectors stacked face to face



No inactive area between detectors

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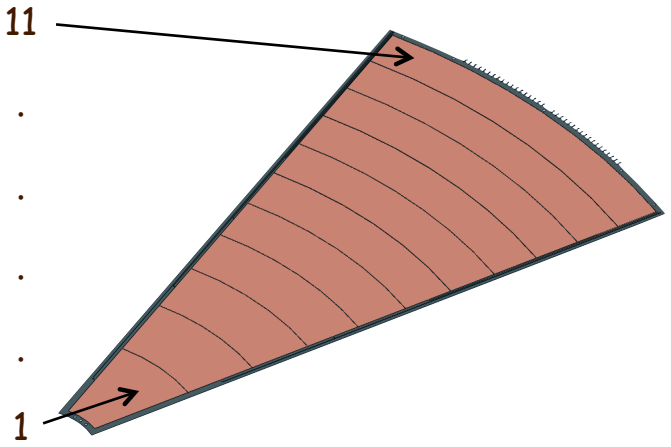
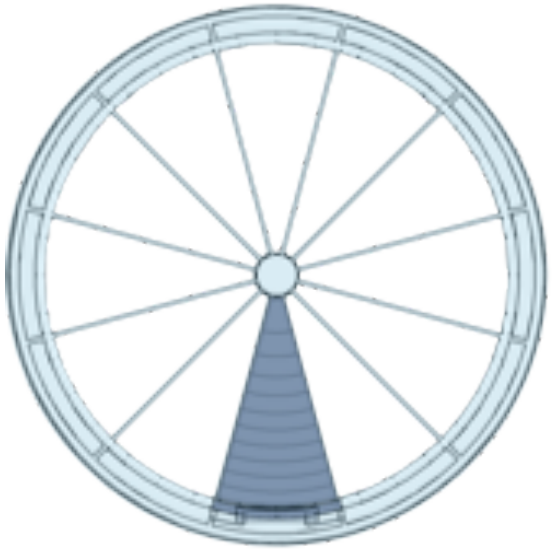
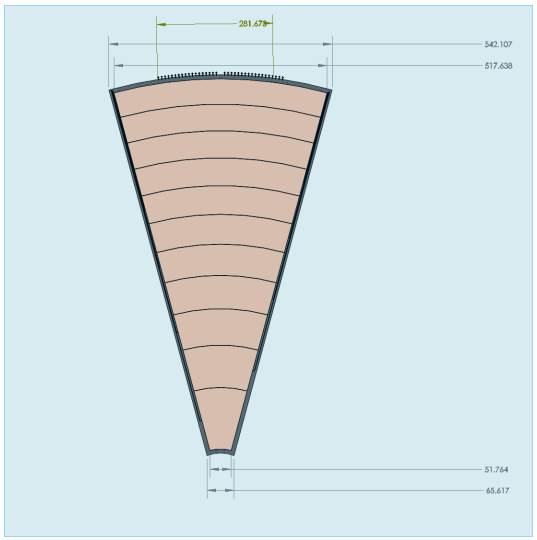
Large triple-GEM design work

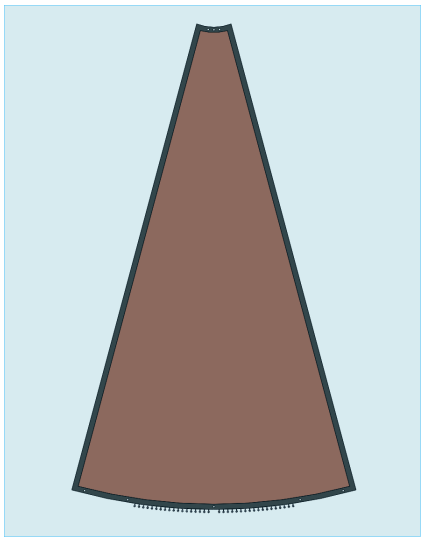
- GEM foil design
  - 103cm x 54.2cm foils (Base material width limit ~55cm)
  - Divided into 11 HV sectors of 100cm^2 (1st sector) to 310cm^2 (11th sector)







Top view



Bottom view

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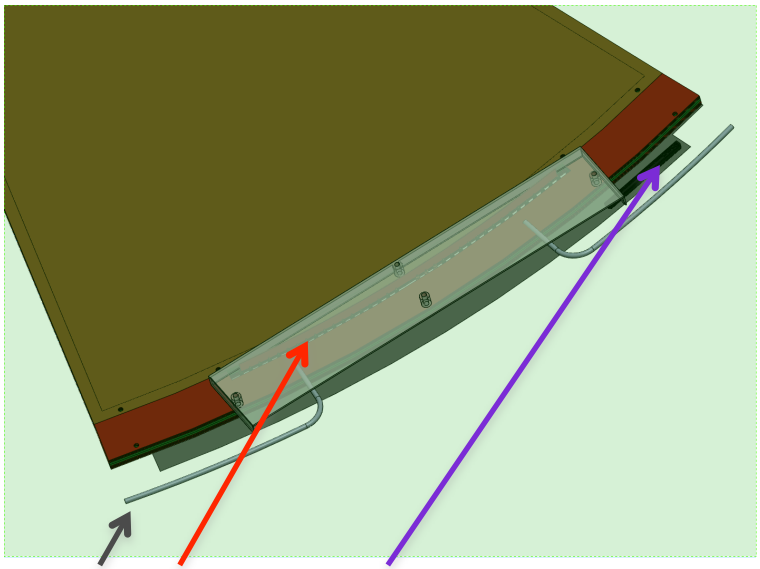
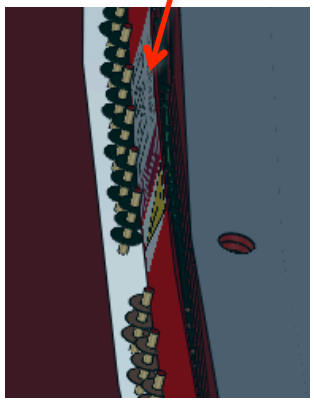
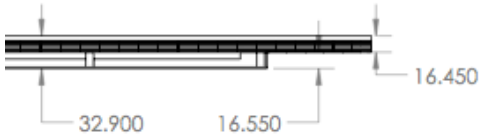
Large triple-GEM design work

- Triple-GEM detector design

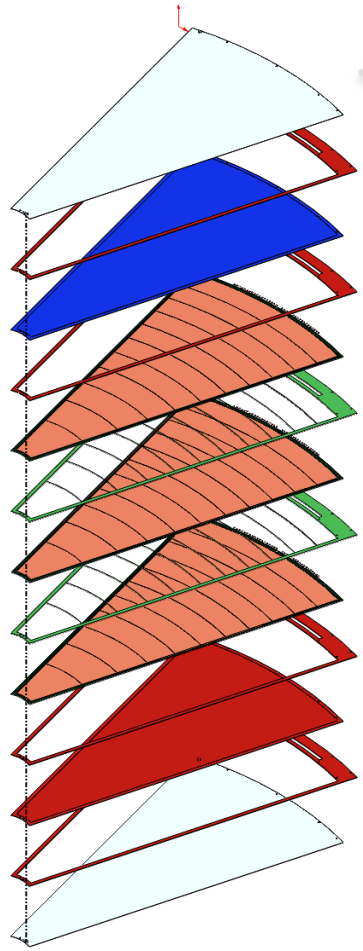


Gas, HV, and readout connections





16.45 mm thick
+ service box



Exploded view of the GEM detector

Mylar foils plus spacer

Cathode (HV)

3 mm spacer (Drift volume)

3 x GEM foils + 2mm spacer grid

2mm spacer (Induction gap)

Readout electrode

spacer + Mylar foil

Lightweight (<1% X_0 in active area)

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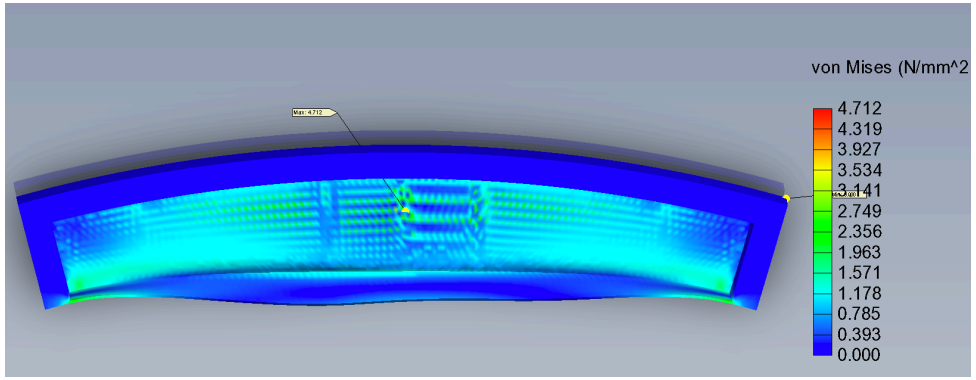
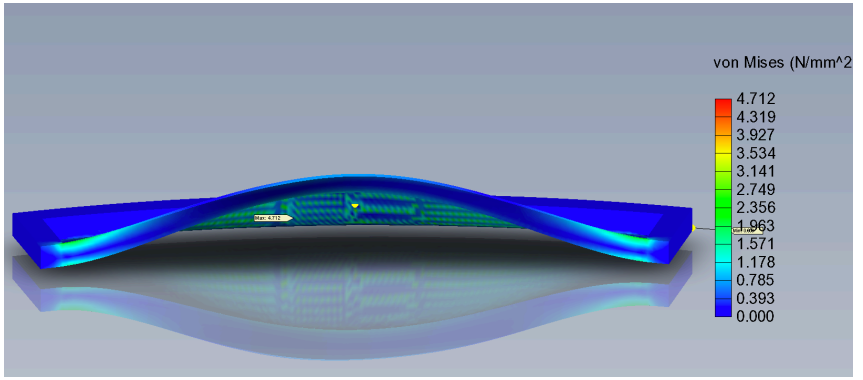
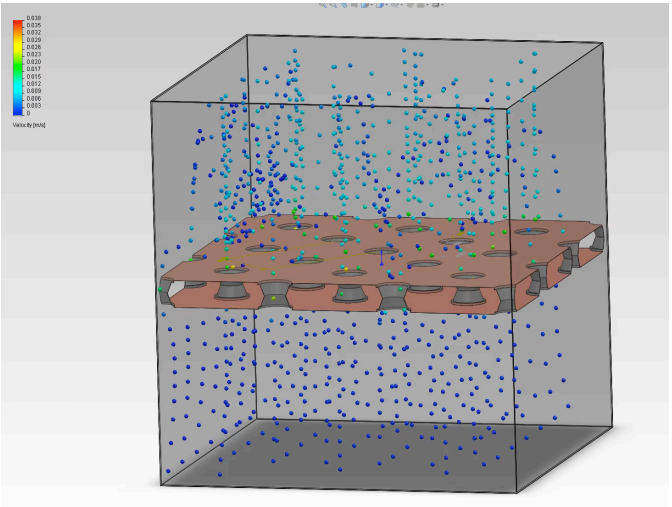
Large triple-GEM design work

- SolidWorks capabilities
  - Mechanical deformation studies





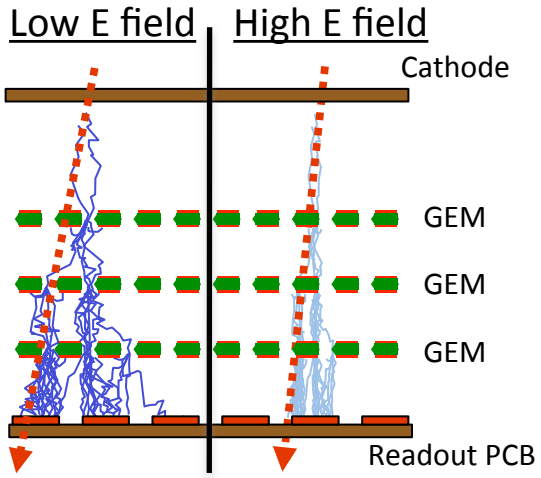
  - Gas Diffusion inside the detector



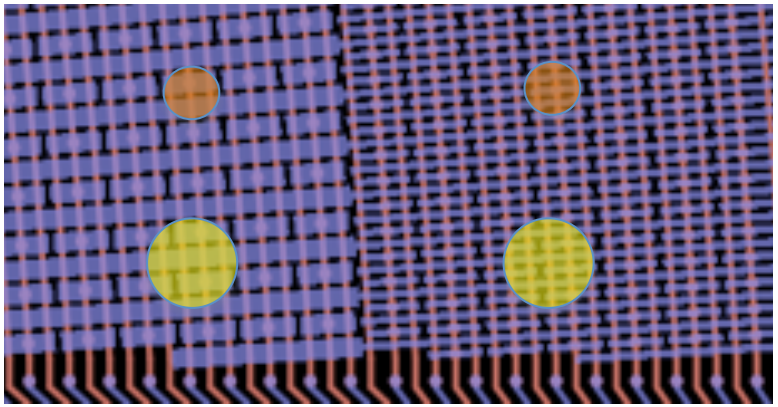
  - Tools ready for further studies!

Large triple-GEM design work

- 2D Readout foil design (1)
  - Commercial fabrication by Tech-Etch Inc.
  - Signal size depends on electric field configuration



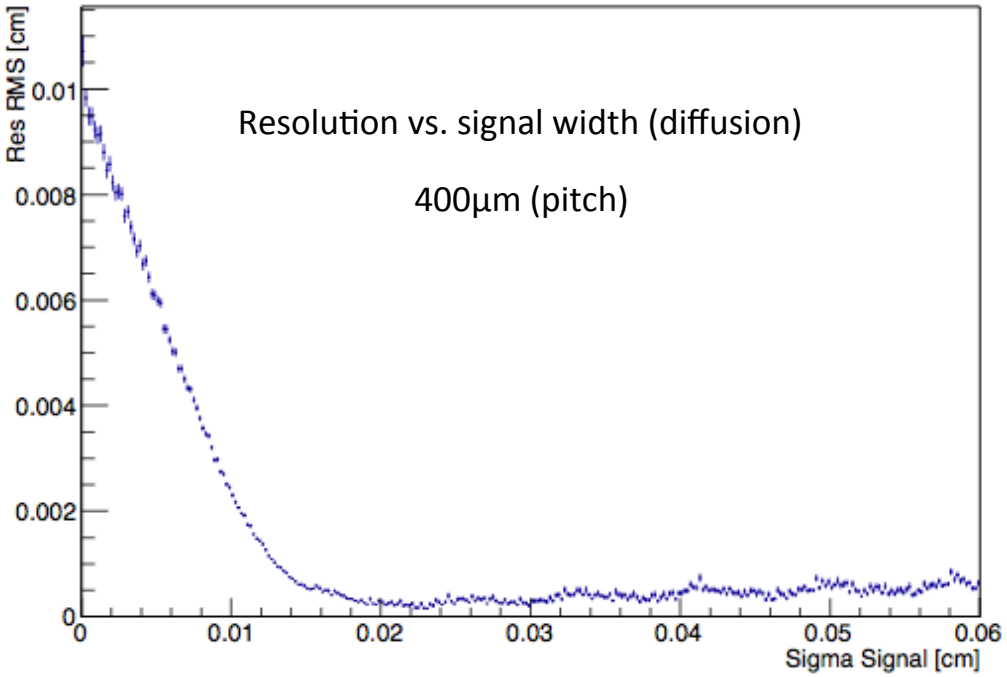
Triple GEM amplification with ≠ HV conf.

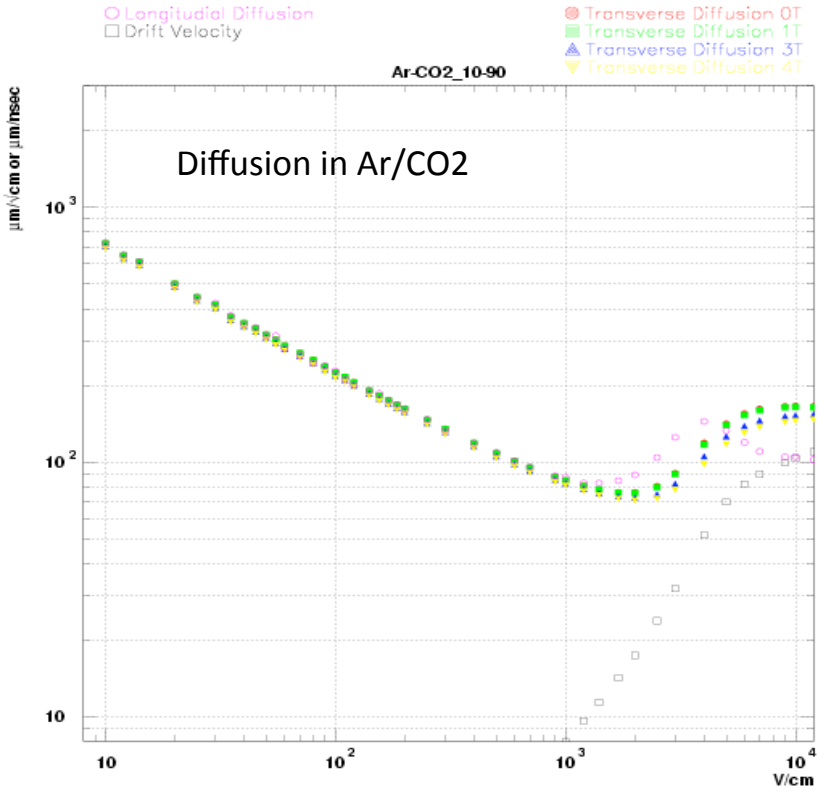


Optimization of the signal size vs. electrode pitch

Large triple-GEM design work

- 2D Readout foil design (2)
  - Simulation of the spatial resolution for a given electrode size





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Summary

- Plans / Schedule
  - Lab setup
    - Complete both labs in current Physics Department by the end of December 2012
    - Install all test equipment during the month of January 2013
  - Training
    - Students form teams
    - Main focus for spring 2013 semester: CCD scans / Leakage current measurements
  - Simulations
    - Graduate student will continue with 'analytical' work
    - Main focus for spring 2013: Geometry and material implementation in GEANT4
  - Triple-GEM design
    - Contact water-jet cutting company (Boston, MA) to obtain and test frames with embedded spacer grid
    - Request prototype samples and perform stretch / sag tests and measurements
  - GEM foil / 2D readout foil
    - Finalize prototype layout of large GEM foil / Prepare Gerber file and discuss with CERN colleagues
    - Discuss concept of large 2D readout foil with Tech-Etch Inc. and identify critical items over FGT production
    - Tech-Etch Inc. agreed to start with preparing single mask process for 10cm X 10cm samples / Test and Characterize
  - Prepare and request supplemental funding request in spring 2013 for continued support!